

Recent results on Top quark Physics with the ATLAS and CMS experiments

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An overview of the most recent results on top quark physics obtained using proton-proton collision data collected with the ATLAS and the CMS experiments at 7 TeV center-of-mass energy is given. Measurements for inclusive and differential top quark pair or single top quark production in different final states are reviewed. Top properties such as W helicity in top decays, electric charge, charge asymmetry and spin correlations of top quark pairs, among others have also been measured by the LHC experiments. All the measurements are found to be consistent with the Standard Model predictions with a good level of accuracy. The latest results in the measurement of the top quark mass at the LHC are also presented and discussed.

1 Introduction

The Large Hadron Collider (LHC) has performed extraordinarily well throughout the year of 2011 providing both the ATLAS¹ and the CMS² experiments with over a million top quarks each. The top quark is one of its kind - it has a mass close to an atom of Gold and a large width which makes it decay before it transverses any significant distance to disturb the color field giving rise to non-perturbative effects such as its fragmentation and hadronization³. Therefore all properties of the “naked” quark are preserved in the decay chain of a top quark. Interestingly there are also many unknowns in the top quark sector, namely on the role it plays in the electroweak symmetry breaking mechanism (EWKSB) given that it is the heaviest fundamental particle and that its mass is close to the EWKSB scale. The ATLAS and CMS experiments have eagerly analysed the data they have collected seeking to understand better the top quark production and its basic properties such as: mass, charge, branching ratios and kinematics of the decay products. In these proceedings we can hardly condense the rich top quark programme at the LHC so we highlight the most recent results obtained by the two collaborations and refer the interested reader to the web pages with the public results^{4,5}.

2 Top quark production

2.1 Top pair production

At the LHC the top pairs are mostly ($\approx 90\%$) produced through gluon-gluon fusion. The measurement of the $t\bar{t}$ cross section has been carried out in all the different final states which result from the combinatorics of the W boson decays, since the top quark decays mostly in the $t \rightarrow Wb$ channel. The $t\bar{t}$ decay channels comprise therefore fully-hadronic (46%), lepton+jets (45%) and

dileptonic (9%) final states. The most precise measurement is obtained in the lepton+jets channel due to both its high statistics and the strategy followed by both experiments.

In the lepton+jets channel the main backgrounds are due to QCD multijets, W +heavy flavour. While the transverse energy flux in QCD multijets processes is expected to be well balanced, constraining these processes in the lower region of the missing transverse energy (E_T^{miss}), and transverse mass (M_T^a) spectra, this is no longer the case for W events. Therefore, given the similarities of the W +jets background and the signal, the strategy adopted by both the ATLAS and CMS experiments is to analyse different categories of events according to the jet multiplicity and the number of b -tagged jets, i.e. identified as b jets. This procedure has the advantage of being able to constrain the actual contamination from background processes which are expected to have lower jet multiplicity than the signal (i.e. <4 jets) and lower heavy flavour content (i.e. b jets). The cross section is extracted after fitting either a simple and robust variable as the mass of the secondary vertex for the jets (CMS⁸) or a multivariate discriminator based on the kinematics of the event (ATLAS⁶) to the different event categories. The fit takes into account not only the normalisation of the background processes but also how it can be affected by the different systematic uncertainties such as jet energy scale, b -tag or mistag efficiencies, the contamination from initial/final state radiation (ISR/FSR) and the factorisation and renormalization scales used to model the signal and some of the backgrounds (i.e. Q^2 scale). The relative uncertainty in the measurement of the $t\bar{t}$ cross section by the ATLAS collaboration is $\approx 7\%$ and it is dominated by the uncertainty in modelling of the signal component and by the measurement of the luminosity.

In the remaining channels the $t\bar{t}$ production cross section has been carried out mostly through counting experiments with the exception of: the fully hadronic channel, which has used a fit to the distribution of the reconstructed top mass with a kinematics fit (CMS) or the $\min \chi^2$ assuming $m_{\text{top}} = 172.5 \text{ GeV}/c^2$ found from all possible jet combinations in the event (ATLAS), and the τ channels where a multivariate analysis is used (ATLAS). Overall the results are compatible with the theoretical predictions but its uncertainties tend to be larger with respect to the measurement in the lepton+jets channel due to systematic effects such as jet energy scale or background estimations.

Figure 1 summarises the results obtained in the different channels and the final combination. The total uncertainty attained by each experiment has now surpassed the theoretical uncertainty at approx. NNLO.

Besides inclusive $t\bar{t}$ measurements the associated production with a photon has also been measured by the ATLAS collaboration and the results are found to be in good agreement with the SM predictions: $\sigma(t\bar{t}\gamma) = 2.0 \pm 0.5_{\text{stat}} \pm 0.7_{\text{syst}} \pm 0.08_{\text{lumi}} \text{ pb}^7$.

With the large statistics sample acquired in 2011 the inclusive measurements were also expanded to measure differential cross sections such as $t\bar{t} + N$ jets, $p_T^{t\bar{t}}$, p_T^{top} , $M_{t\bar{t}}$, among others.

Differential measurements were carried out in the lepton+jets and dilepton channels after the reconstruction of the $t\bar{t}$ kinematics⁹. In the lepton+jets this is achieved after choosing the combination of jets which yields the best kinematical fit. In the dilepton channel due to the presence of two neutrinos in the final state, and therefore unconstrained kinematics, the solutions for the kinematics are found scanning m_{top} in the $[100, 300] \text{ GeV}/c^2$ and compared with the simulated expectations for the neutrino kinematics. The solution with larger probability which makes use of the highest number of b -tagged jets is used. These arbitrations in the choice of the kinematics may lead to misassignment of the objects or to event rejection in case the algorithm fails to find a valid solution. These effects lead to an additional smearing of the reconstructed kinematics (on top of the detector resolution effects). This effect is minimised by unfolding the reconstructed kinematics to parton level. A Singular Value Decomposition (SVD) technique is

^aThe transverse mass of a single lepton event with p_T^ℓ and the E_T^{miss} is defined as $M_T = \sqrt{2(1 - \cos \delta\phi)p_T^\ell E_T^{\text{miss}}}$, where $\delta\phi$ is the angle between the lepton transverse momentum and the E_T^{miss} direction.

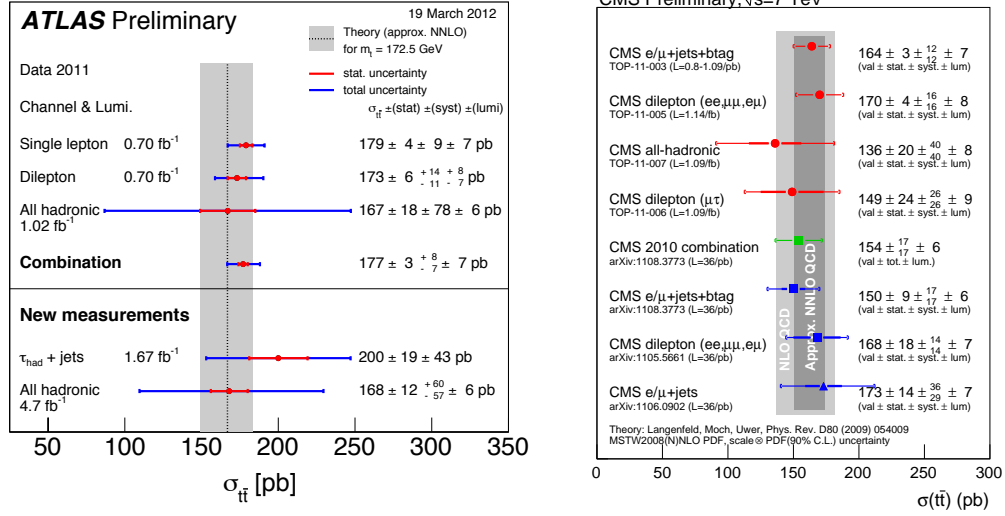


Figure 1: Summary of the $t\bar{t}$ cross section measurements at $\sqrt{s}=7 \text{ TeV}$ performed by the ATLAS (*left*) and CMS (*right*) collaborations. Different theoretical predictions are shown as represented as vertical bands.

applied and the widths of the bins (Δ_x^i) of each kinematical variable are chosen in order to keep the purity and stability above 50%. The differential cross section is measured after background subtraction and unfolding the observed value.^b Overall the agreement between the unfolded data and the simulation is remarkable but the uncertainty attained is not yet at the level where one signal model can be preferred among the ones studied. One distribution of particular interest is $p_T^{t\bar{t}}$ and it is shown in Fig. 2 (*left*).

The measurement of $t\bar{t} + N$ jets is correlated with the $p_T^{t\bar{t}}$ spectrum and it assesses from data how well the recoil of the $t\bar{t}$ system and the modelling of ISR are predicted theoretically and by the simulation. The lepton+jets channel has been used to study the associated production with $t\bar{t}$ with extra jets¹⁰. After background subtraction the jet multiplicity spectrum is compared to the simulated prediction using Acer MC¹¹. The nominal prediction is obtained after performing the parton showering with the Pythia generator¹² and can be varied in two ways by enhancing or suppressing: i) the ISR branching above the coherence scale; ii) the α_{QCD} evolution scale of the ISR (effect is proportional to $\Lambda_{\text{ISR}}^{-1}$). The measurement is dominated by the uncertainties in the jet energy scale and in the subtraction of the background. Even if compatible with the nominal prediction for the ISR in $t\bar{t}$ events it has not yet attained the necessary precision to constrain further the modelling of the production of extra jets in this sample.

2.2 Single top production

Single top quarks can be produced through the s- and t-channels and in association with a W boson. Table 1 summarises the current status of the measurement of the single top production cross section at the LHC^{13,14,15,17,16} and compares the results with the theoretical predictions^{18,19,20}. With the exception of the s-channel which will require larger amount of integrated luminosity to be observed, the agreement between experiment and theory for the single top production cross section is remarkable. In the following we summarise briefly the strategies followed to extract these cross sections from data.

The dominant production mode is the t -channel and it is characterised by one central isolated

^bThe differential cross section with respect to a kinematical variable x is usually expressed as $1/\sigma \cdot d\sigma^i/dx = 1/\sigma \cdot (N_{\text{data}} - N_{\text{background}})/\Delta_x^i \varepsilon^i \mathcal{L}$ where ε^i is the efficiency correction for the i^{th} bin and \mathcal{L} is the total integrated luminosity.

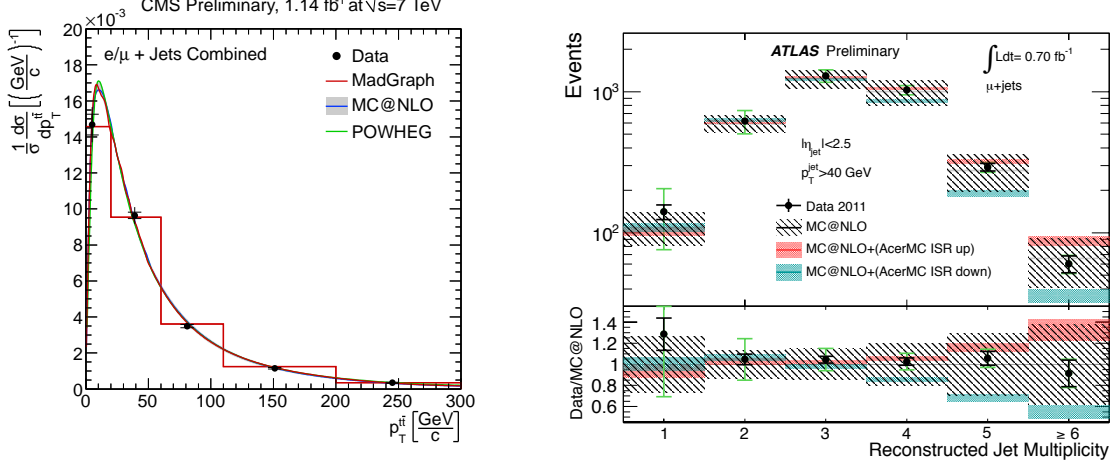


Figure 2: Differential cross section measurements in the lepton+jets channel. *Left*: The transverse momentum of the top quark pair obtained after unfolding is compared to different MC generators. *Right*: The jet multiplicity distribution after background subtraction is compared to the nominal and varied ISR showering predictions.

Table 1: Summary of the experimental and theoretical cross sections for single top production in the different channels. See text for references.

Channel	σ_t (pb)	σ_{tW} (pb)	σ_s (pb)
ATLAS	$83 \pm 4(\text{stat})^{+20}_{-19}(\text{syst})$	$14.4^{+5.3}_{-5.1}(\text{stat})^{+9.7}_{-9.4}(\text{syst})$	< 26.5 @ 95% CL
CMS	$70.2 \pm 5.2(\text{stat}) \pm 10.4(\text{syst}) \pm 3.4(\text{lumi})$	$22^{+9}_{-7}(\text{stat} \oplus \text{syst})$	-
Theory	$64.57^{+2.09}_{-0.71} {}^{+1.51}_{-1.74}$	$15.74 \pm 0.40^{+1.10}_{-1.14}$	$4.63 \pm 0.07^{+0.19}_{-0.17}$

lepton accompanied by E_T^{miss} , a b -jet and a forward high p_T recoiling jet. Due to the proton PDFs we expect that the ratio between single top and single anti-top produced through the t -channel to be ≈ 1.9 . The main backgrounds to this channel are due to QCD multijets and W +heavy flavour production. The first type of background can be controlled in a sideband where the lepton is non-isolated and a template for the E_T^{miss} or M_T distribution can be derived and used as input to fit in the signal region. The second type of background is almost irreducible and can at most be constrained (by splitting the data sample in different categories according to the jet and b -tag multiplicities, or failing a requirement on the reconstructed top quark mass from the lepton- E_T^{miss} - b -jet system) or partially discriminated (with a multivariate analysis). Both approaches have been followed: ATLAS measures the cross section by fitting the distribution of a multivariate discriminant constructed with a neural network and the most recent result, from CMS, uses a fit to a simple and robust variable - the pseudo-rapidity of the recoil jet - to extract the production of single top in the t -channel. The result is used to measure the CKM matrix element V_{tb} and the result obtained is: $|V_{tb}| = 1.04 \pm 0.09$ (exp) ± 0.02 (th) (CMS).

Both experiments are close to find evidence for single top production in the tW -channel using dilepton events. The definition of this channel overlaps partially with the $t\bar{t}$ process when one of the top quarks is virtual. The distinctive feature of the tW channel is the presence of a single b -jet in the majority of the events and the fact that at LO the decay products of the top and the W boson balance each other. Both experiments extract the tW cross section from a likelihood fit for counts of events with n -jets and k b -tags. Even if the signal is absent from high multiplicity events these control regions help further in constraining the $t\bar{t}$ contribution.

The rarest, and nevertheless most interesting of the channels, is the s -channel which is expected to be sensitive to new physics. Although not yet observed, the ATLAS experiment has put upper limits on the cross section value from a kinematics analysis. The $S/B^{1/2}$ expected is 0.98.

3 Top quark properties

With large statistics samples many properties can be measured accurately. The main challenge is to constrain the systematic uncertainties which in many case dominate the final uncertainty. Part of these uncertainties can indeed be constrained from data as we have highlighted in the previous section: ISR/FSR and Q^2 -scale are some examples.

Information on spin correlation of the $t\bar{t}$ system is preserved by the decay products. It is found that the degree of information is maximal in the lepton and down-type quark kinematics. The measurement can be performed in two alternative ways: i) reconstructing the full kinematics and studying the $t\bar{t}$ system in a specific reference frame (usually the helicity basis where the system is at rest or a maximal frame which is defined event by event from the top kinematics with respect to the beam-line); ii) using a simple robust variable reconstructed from a high purity final state and translate it to a reference frame. The second strategy was pursued by the ATLAS experiment to find evidence for spin correlations in $t\bar{t}$ production²². The difference in the azimuthal angle of the dilepton candidates is fit using templates for the predictions within the SM and in the absence of correlations. The distribution is shown in Fig. 3 (*left*) and it depicts both the high purity of the sample and the evidence for correlation of the two leptons. The result of the fits is in good agreement with the SM prediction and the asymmetries measured are: $A_{\text{helicity}} = 0.34 \pm 0.07_{\text{stat}} \pm 0.13_{-0.09}^{\text{syst}}$ ($A_{\text{helicity}}^{\text{SM}} = 0.32$) and $A_{\text{maximal}} = 0.47 \pm 0.09_{\text{stat}} \pm 0.18_{-0.12}^{\text{syst}}$ ($A_{\text{maximal}}^{\text{SM}} = 0.44$). The quoted SM predictions were computed with MC@NLO and CTEQ6.6 PDF. The systematic uncertainty is at this point dominated by the effects of ISR and signal modelling.

The top quark charge has also been measured using the charge of the decay products^{23,24}. The charge can be measured directly from the lepton from the W decay and from the b -jet. In the latter case two possibilities can be used: using a charge estimator based on the tracks associated to the jet or using semi-leptonic B decays which minimize charge assignments but are prone to sub-decays or oscillations of the B hadrons. Both cases can be optimised and have its efficiency measured from the abundant QCD $b\bar{b}$ production. The events are counted in two charge possibilities ($2e/3$ or $4e/3$) and from the observed asymmetry an upper limit on exotic scenarios is set. Both experiments set a $> 5\sigma$ limit on exotic top quark charge production.

Both ATLAS and CMS have searched for deviations in the SM predictions for the EWK couplings of the top quarks. Although the top quark is primarily expected to couple to a Wb vertex, Flavour Changing Neutral Currents (FCNC) may contribute because of the presence of new physics. Anomalous tWb couplings can also be enhanced by the presence of new physics.

The search for FCNC in $t\bar{t}$ events has been carried out in trilepton events where one $t \rightarrow Zq \rightarrow \ell\ell q$ is produced. In this topology the full kinematics of the event is specified (the $E_{\text{T}}^{\text{miss}}$ is the direct signature of the escaping neutrino) and the objects can be assigned to each top decay by using a kinematics fit or by requiring one of the jets to be b -tagged. This search is mostly expected to be dominated by the statistical uncertainty due to small presence of backgrounds (other than di-boson production). The full 2011 dataset is used by the CMS experiment to set an upper limit of $\mathcal{B}(t \rightarrow qZ) < 0.34$ ²⁵ and limits are also provided by ATLAS²⁶. Evidence for FCNC can also be sought in single top production. The signature is challenging experimentally as $qg \rightarrow t \rightarrow W(\rightarrow \ell\nu)b$ is characterised by a single lepton + b jet + $E_{\text{T}}^{\text{miss}}$ final state which is contaminated mostly by W +heavy flavour production. The ATLAS collaboration has explored the topology of the signal via a multivariate analysis. The signal

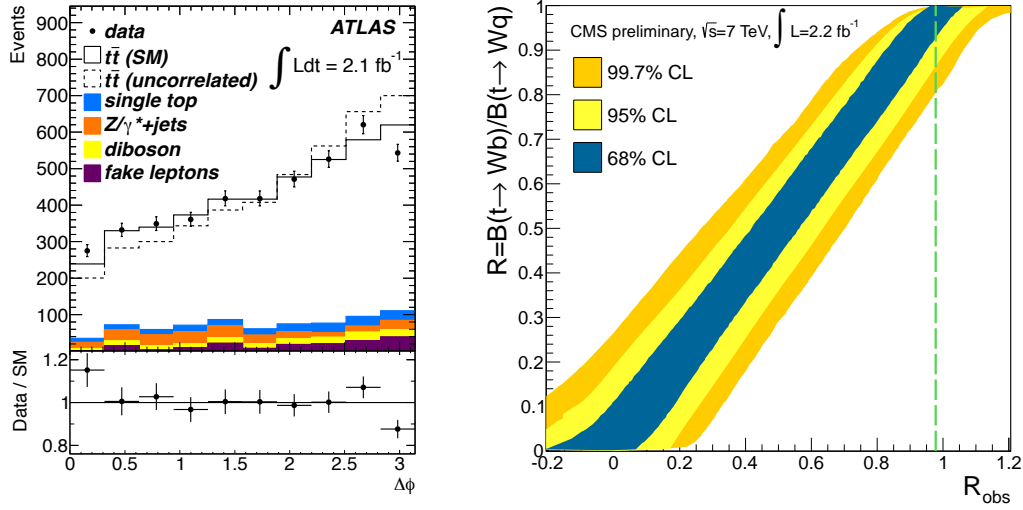


Figure 3: *Left:* Difference in the azimuthal angle of dilepton $t\bar{t}$ candidates. The data observed is compared with the SM prediction (signal+ background) and with a possible scenario where the $t\bar{t}$ pair is produced without any spin correlation. *Right:* Limit bands at different CL on \mathcal{R} with the measured value overlaid as a dashed line. The favoured values of \mathcal{R}_{obs} obtained for different CL (horizontal axis) are shown for each true value of \mathcal{R} (vertical axis).

is mostly characterised by the fact that: i) top quarks are produced at rest; ii) W bosons are boosted (with $m_T + E_T^{miss} > 60$ GeV) iii) $N(t)/N(\bar{t}) \sim 4$; An upper limit is set on the production cross section $\sigma_{qg \rightarrow t}^{obs} < 3.9$ pb at 95% CL (with an expectation of $\sigma_{qg \rightarrow t}^{exp} < 2.4$ pb). Limits on FCNC decays of the top quark are set in the $\mathcal{B}(t \rightarrow ug)$ versus $\mathcal{B}(t \rightarrow cg)$ plane yielding $\mathcal{B}(t \rightarrow ug) < 5.7 \cdot 10^{-5}$, if $\mathcal{B}(t \rightarrow cg) = 0$, and $\mathcal{B}(t \rightarrow cg) < 2.7 \cdot 10^{-4}$, if $\mathcal{B}(t \rightarrow ug) = 0$. More details can be found in ²¹.

A generic estimator for deviations of the predicted $\mathcal{B}(t \rightarrow Wb)$ is the measurement of $\mathcal{R} = \mathcal{B}(t \rightarrow Wb)/\mathcal{B}(t \rightarrow Wq)$. This measurement was made from the modelling of the b -tag multiplicity distribution observed in $t\bar{t}$ dilepton events which are expected to be highly pure in signal. The residual background and the model for the counted b -tags is derived from data taking into account not only the b -tag and mistag probabilities (as measured from QCD dijet events, an orthogonal sample) but also the probability to fully reconstruct and accept in the event the decay products of a top quark decay. The result is well in agreement with the SM prediction: $\mathcal{R} = 0.98 \pm 0.04$ (stat+syst) and a lower endpoint for the confidence interval at 95% CL is set using the Feldman-Cousins approach: $\mathcal{R} > 0.85$ ²⁷.

The decay products of the top quark can be further analysed to look for deviations from the SM predictions. The polarisation of the W boson is of great interest as new physics might lead to anomalous tWb couplings. Given the fact that spin information is preserved and that the b quark has an almost negligible mass compared to the top and the W , the SM predicts, through the V-A couplings, that the W bosons from top quark decays are mostly longitudinally polarised ($F_0 = 0.687 \pm 0.005$) or left-handed ($F_L = 0.311 \pm 0.005$) ²⁸. The presence of anomalous couplings would thus lead to deviations of the fractions of polarised W bosons. These fractions can be derived from the distribution of the angle between the lepton from the W decay and the b -jet from the same top decay, evaluated in the W boson rest frame. In first approximation $\cos \theta^* \approx 4p_b \cdot p_\ell / (m_T^2 - m_W^2) - 1$. The experimentally observed distribution has to be corrected for experimental effects such as acceptance (introduced by the selection) and resolution (mostly from the jets). Moreover the theoretical prediction needs to take properly into account effects such as the Q^2 , ISR/FSR, mass of the b quark. In order to interpret the observed spectrum

Table 2: Measured fractions of longitudinally, left- and right-handed polarisation by the ATLAS and CMS collaborations. The statistical and total systematic uncertainties are shown separately. The limits on the anomalous couplings (and effective operator coefficients) are also included when available.

Measurement	ATLAS	CMS
F_0	$0.67 \pm 0.03 \pm 0.06$	$0.57 \pm 0.07 \pm 0.05$
F_L	$0.32 \pm 0.02 \pm 0.03$	$0.39 \pm 0.05 \pm 0.03$
F_R	$0.01 \pm 0.01 \pm 0.04$	$0.04 \pm 0.04 \pm 0.04$
$\text{Re } V_R \text{ (Re } C_{33}^{\phi\phi}/\Lambda^2)$	$[-0.20, 0.23] \text{ } ([-6.7, 7.8])$	-
$\text{Re } g_L \text{ (Re } C_{33}^{dW}/\Lambda^2)$	$[-0.14, 0.11] \text{ } ([-1.6, 1.2])$	-
$\text{Re } g_R \text{ (Re } C_{33}^{uW}/\Lambda^2)$	$[-0.08, 0.04] \text{ } ([-1.0, 0.5])$	$[-0.17, 0.02] \text{ } ([-1.9, 0.2])$

based on general polarisation scenarios a re-weighting procedure may be applied taking into account all these effects (CMS²⁹) or using dedicated samples generated with Protos³⁰ (ATLAS³¹). ATLAS introduces further the measurement of the asymmetries of the spectrum which are robust estimators less prone to the effect of some of the systematic uncertainties. The angular asymmetries are defined in such a way that the F_L and the F_R contributions are allowed to cancel out: $A_{\pm} = [N(\cos \theta^* > z) - N(\cos \theta^* < z)] / [N(\cos \theta^* > z) + N(\cos \theta^* < z)]$, where $z = \pm(1 - 2^{2/3})$. Table 2 summarises the results obtained for the contributions from differently polarised W bosons. A good agreement is found with respect to the SM predictions and the results are used to set limits on anomalous tWb couplings.

We conclude the summary of the measurements of the top quark properties with a discussion on the top pair charge asymmetry which is expected to be highly sensitive to new physics effects³². In $p - p$ collisions the asymmetry manifests through a preferential production of top quarks in the forward direction due to the fact that the anti-quarks from the proton's sea tend to carry a lower momentum fraction. The quantity of interest is therefore the charge asymmetry which can be written as $A_C = (N^+ - N^-)/(N^+ + N^-)$ where N^+ (N^-) is the number of events with $\Delta\eta = |\eta_t| - |\eta_{\bar{t}}| > 0$ (< 0)^c. The asymmetry is measured in lepton+jets events. In order to reconstruct the kinematics of the top and anti-top complementary approaches are used: i) a kinematics fit (based on a likelihood approach) that assesses the compatibility of the observed event with the decays of a top-antitop pair³⁵; ii) the full reconstruction of the leptonically decay W and the top which originated it (after complementing with a selected jet) followed by the reconstruction of the second top from three selected jets³³. In the latter case a probability is defined for each jet permutation and the combination with larger probability is used to reconstruct $|\Delta\eta|$ (expected to be correct in 72% of the cases). After background subtraction of the reconstructed events an unfolding procedure is applied to recover the parton level kinematics. CMS applies a regularised unfolding procedure to the data through a generalised matrix-inversion method using twice as many bins for the uncorrected as for the corrected spectrum. ATLAS uses a bayesian approach to invert the response matrix in order to find the corrected spectrum. Both experiments measure an asymmetry which is compatible with the NLO prediction: $A_C^{\text{NLO}} = 0.0115 \pm 0.0006$ ³⁴. ATLAS measures $A_C = -0.018 \pm 0.028_{\text{stat}} \pm 0.023_{\text{syst}}$ using 1.04 fb^{-1} while CMS measures $A_C = 0.004 \pm 0.010_{\text{stat}} \pm 0.012_{\text{syst}}$ using 4.7 fb^{-1} . Differential measurements of the asymmetries have been carried out namely as function of p_T , y and invariant mass ($M_{t\bar{t}}$) of the $t\bar{t}$ pair and found to be consistent with the NLO predictions. The dependency of A_C as function of any of these variables has been compared to BSM models (ATLAS) or to Effective Field Theory (CMS) and no hints for contributions from physics beyond the standard model have been found. Figure 4 (*left*) shows the differential measurement of A_C as function of $M_{t\bar{t}}$ as obtained by the CMS experiment. The ATLAS collaboration has used its results to set stringent

^cThe events can also be counted using $\Delta y^2 = (y_t - y_{\bar{t}})(y_t + y_{\bar{t}}) = (y_t^2 - y_{\bar{t}}^2)$ as alternative variable.

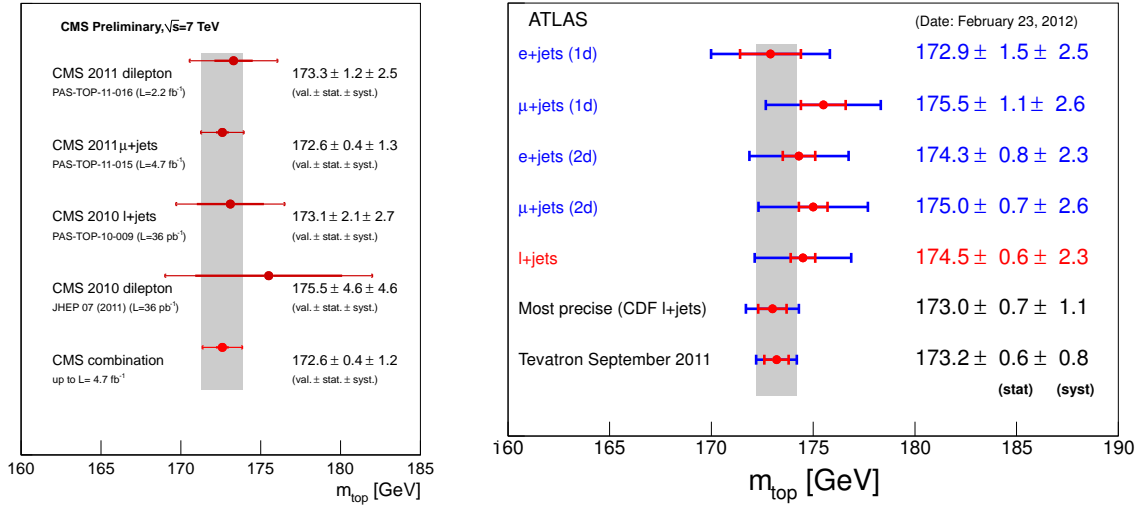


Figure 5: Summary of the top mass measurements carried by the ATLAS (*left*) and CMS (*right*) experiments.

has also performed a combined fit of m_{top} in the lepton+jets channel employing an ideogram technique³⁸. After a kinematic fit an event likelihood is defined by taking into account the expected contribution from correct assignments, wrong permutations and also $t\bar{t}$ events where at least one of the decay products (jet or lepton) has not been properly reconstructed or selected. Background events are also taken into account. The individual event likelihoods are combined in the sample allowing one to extract m_{top} (and JES) from the maximum likelihood found. The top mass is measured to be: $m_{\text{top}} = 172.6 \pm 0.6_{\text{stat}} \pm 1.2_{\text{syst}}$ GeV/ c^2 with the systematic uncertainty being dominated by the modelling of the signal namely the choice of the Q^2 and jet-parton matching scales and by the uncertainty in the flavour-specific JES corrections. The effects of CR and underlying event tune on this measurement are currently being evaluated by the experiment.

The top quark mass has also been measured in the dilepton channel by the CMS experiment employing the KIN_b method which solves numerically the equations for the kinematics of the $t\bar{t}$ pair decay using different hypothesis for the $t\bar{t}$ imbalance along the beam line according to the expectations from simulation. In this case the measurement is dominated by the JES uncertainty followed by the modelling of the signal and $m_{\text{top}} = 173.3 \pm 1.2_{\text{stat}} \pm 2.6_{\text{syst}}$ GeV/ c^2 is obtained³⁹.

Figure 5 summarises the different top mass measurements carried out by the LHC experiments. A good agreement with the Tevatron measurements is found and the overall uncertainty attained by each experiment starts to be competitive with the most precise measurements⁴⁰. A combination of these measurements, once all the uncertainties are estimated is expected to yield a significant improvement in the knowledge of m_{top} .

The difference between the top/anti-top masses has also been measured at the LHC. The observation of a deviation from the null result is a signature of CPT violation in the top quark sector. In this measurement many systematic uncertainties cancel out as a difference between masses is measured. The CMS collaboration has reconstructed m_{top} from the μ^\pm +jets samples using a kinematic fit and the combination of jets with lowest χ^2 . The final measurement of the mass in each sample is taken after combining the event-per event likelihood with the ideogram method. The result obtained is in good agreement with the SM prediction and it is currently statistically limited: $\Delta m_{\text{top}} = -0.44 \pm 0.46_{\text{stat}} \pm 0.27_{\text{syst}}$ GeV/ c^2 ⁴¹.

5 Summary

The LHC experiments have entered the precision era for top quark physics. The results presented indicate an excellent agreement with the theoretical predictions in all aspects explored so far. The challenge laying ahead is the reduction of the systematic uncertainties either from more precise theoretical computation either by constraining some of these uncertainties from data (e.g. ISR/FSR contribution, Q^2 scale, CR effects). More precise characterisation of the top quark will help to shed light on the EWKSB mechanism and the role the top quark plays in it. Precision measurements of the top quark production environment will be of great value in the continuation of searches for new physics to which the top constitutes an important background.

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